Molecules, Atoms, Grams and Mole Calculation Practice

Helpful HINTS: In these problems look for two things:
1) From what unit to what unit?
2) Does the object stay the same, or does the object change? (e.g. molecules to molecules is when the object stays the same, molecules to atoms is when the object changes).

EXAMPLES Involving Atoms:
When dealing with atoms by themselves, for example, atoms of a noble gas (Ar, Xe, Kr) or atoms in a metal (Cu, Zn, Na) and not as part of a molecule or polyatomic ion, then we do not convert to ions or molecules.

Example1
How many moles of Ar are there in a sample of gas that contains 2.84 x 10^{25} Ar atoms?
Overall: We are starting with units of **Ar atoms** and our answer should be in units of **moles of Ar. The object stays the same.** Since Ar is by itself, we cannot convert to a larger unit at the molecular level. We go straight to moles using Avogadro's number.
Step 1: Convert atoms to moles.

$$\frac{2.84 \text{ x } 10^{25} \text{ Ar atoms}}{1} \times \frac{1 \text{ mole Ar}}{6.02 \text{ x } 10^{23} \text{ Ar atoms}} = 47.2 \text{ moles Ar}$$

Example 2
If we had a sample of 32.5 grams of copper, how many copper atoms would be in the sample?
Overall: We are going from units of **grams of Cu** to individual **Cu atoms**. Large to small. We always convert from Large to small going through MOLES. The object stays the same.
Step 1: Find the Molar Mass (units of gram/mole) and convert from grams to moles
Step 2: Use Avogadro's number. The object in this problem is atoms, because a metal Cu is thought of in terms of individual atoms rather than in a molecule. Convert from moles to atoms.

$$\frac{32.5 \text{ g Cu}}{1} \times \frac{1 \text{ mole Cu}}{64 \text{ g Cu}} \times \frac{6.02 \text{ x } 10^{23} \text{ Cu atoms}}{1 \text{ mole Cu}} = 3.06 \text{ x } 10^{23} \text{ Cu atoms}$$

Example 3
If we put 5.76 x 1028 atoms of Zn on a gram balance, what would the balance read?
Overall: Again, Zn is an isolated atom, not part of a molecule or polyatomic ion so we don't have to convert through ions or molecules. The object stays the same. We are going from units of individual **atoms to grams**: small to large.
Step 1: Convert atoms to moles, using Avogadro's number. The object is atoms, because Zn is made of individual atoms.
Step 2: Convert moles to grams using the molar mass.

$$\frac{5.76 \text{ x } 10^{28} \text{ atoms Zn}}{1} \times \frac{1 \text{ mole Zn}}{6.02 \text{ x } 10^{23} \text{ Zn atoms}} \times \frac{65\text{g Zn}}{1 \text{ mole Zn}} = 6.25 \text{ x } 10^{6} \text{ g Zn}$$

EXAMPLES Involving Ions: monatomic ions (e.g. Mg^{2+}) or polyatomic ions (e.g. $Cr_2O_7{}^{2-}$).

Example 4

How many molecules of Na_3PO_4 were dissolved into water, if the solution of water and Na_3PO_4 contains 2.59×10^{12} phosphate ($PO_4{}^{3-}$) ions?

Overall: We are going from individual **ions** to individual **molecules**. The object changes. In this instance, the objects and the units are the same thing. Both of these units are in the molecular or smallest view. We do not need to go to moles or grams for this.

Step 1: Count the number of phosphate ions in the molecule and use that as your conversion factor.

$$\frac{2.59 \text{ x } 10^{12}\ PO_4^{-3}ion}{1} \times \frac{1 \text{ molecule } \mathrm{Na_3PO_4}}{1\ PO_4^{-3}ion} = 2.59 \times 10^{12} \text{molecule } \mathrm{Na_3PO_4}$$

Example 5

How many moles of sodium ions are in a solution that contains 3.889×10^{22} Na^{1+} ions?

Overall: We are going from individual **sodium ions** to **moles of sodium** ions. There are no molecules involved in this problem at all. We are going from sodium ions to sodium ions so we don't have to change objects at all. We are also going from molecular view to the big view.

Step 1: Convert individual ions to moles using Avogadro's number. The object is ions.

$$\frac{3.889 \text{ x } 10^{22}\ \mathrm{Na^{+1}ions}}{1} \times \frac{1 \text{ mole } \mathrm{Na^{+1}ions}}{6.02 \text{ x } 10^{23}\mathrm{Na^{+1}ions}} = 6.46 \times 10^{-2} \text{ moles of } \mathrm{Na^{+1}}$$

Example 6

What is the mass of the sodium ions contained in the solution described in Example 5?

Overall: We are going from individual **sodium ions**, given in example 5, **to grams** of sodium ions. Again, the object stays the same. Since the unit isn't specified, and unit of mass will work.

We can choose grams. In example 5, we found the moles of sodium ions. We can start from that information and go from the moles to the mass using the molar mass of Na. The molar mass of a monatomic ion is approximately the same as the molar mass of its atom.

$$\frac{6.46 \text{ x } 10^{-2} \text{ moles } \mathrm{Na^{+1}}}{1} \times \frac{23\mathrm{g}\ \mathrm{Na^{+1}ions}}{1 \text{ mole } \mathrm{Na^{+1}}} = 1.49 \text{ g of } \mathrm{Na^{+1}}$$

EXAMPLES Involving Atoms and Ions within Molecules:

When dealing with molecules, we may be asked for information about the molecule as a unit, or we can ask questions about the smaller units that make up a molecule: either atoms, monatomic ions (e.g. Mg^{2+}) or polyatomic ions (e.g. $Cr_2O_7{}^{2-}$).

Example 7

How many atoms (total) are in 25.97 grams of carbon monoxide?

Overall: We are going from grams (big view) to atoms (molecular view) and we are going from molecules of CO to atoms (the object changes). We need to convert atoms to moles, the central quantity that we use whenever we go from the molecular view to the big view, or vice versa. We also need to convert from molecules to atoms. We can do that once we are in the molecular view, by counting the atoms in one molecule.

Step 1: Convert grams to moles using the molar mass.

Step 2: Convert moles to molecules (since our object here is a molecule of CO) using Avogadro's number.

Step 3: Convert molecules to atoms by counting the number of atoms in the molecule and using that as the conversion factor., do the same for O and sum two answers.

$$\frac{25.97 \text{ g CO}}{1} \times \frac{1 \text{ mole CO}}{28.01 \text{ g CO}} \times \frac{6.02 \text{ x } 10^{23} \text{ CO molecules}}{1 \text{ mole CO}} \times \frac{1\ atom\ C}{1 molecule\ CO} = 5.58 \text{ x } 10^{23} \text{ C atoms}$$

Example 8
How many sodium ions are in 12.5 grams of Na2SO4?
Overall: We are going from **grams of Na_2SO_4** (big view) to individual **ions of Na^{1+}** (molecular view). In order to go between big view and molecular view, we need to convert through moles, the central quantity. Also note that we are changing objects: going from grams of a **molecule Na_2SO_4 to** monatomic **ions, of Na^{1+}.** So once we convert to moles, we will have to convert to molecules before converting to ions, the smaller component of the molecule.
Step 1: Convert grams **Na_2SO_4** to moles **Na_2SO_4** using the molar mass.
Step 2: Convert moles **Na_2SO_4** to molecules of **Na_2SO_4** using Avogadro's number. The object is a molecule because **Na_2SO_4** is a molecule.
Step 3: Now we are in individual molecules. Determine the number of **Na^{1+}** ions in one molecule and use that as your conversion factor to find individual ions of sodium.

$$\frac{12.5 \text{ g Na}_2\text{SO}_4}{1} \times \frac{1 \text{ mole Na}_2\text{SO}_4}{142 \text{ g Na}_2\text{SO}_4} \times \frac{6.02 \text{ x } 10^{23} \text{ Na}_2\text{SO}_4 \text{ molecules}}{1 \text{ mole Na}_2\text{SO}_4} \times \frac{2 \text{ Na}^{1+}\text{ion}}{1 molecule \text{ Na}_2\text{SO}_4} = 1.06 \text{ x } 10^{24} \text{ Na}^{1+}\text{ion}$$

Example 9
How many moles of potassium in potassium hydrogen phosphate (K_2HPO_4) are there if some potassium hydrogen phosphate has been dissolved in water and there are 5.798 x 10^{18} hydrogen phosphate ions HPO_4^{2-} in that solution?
Overall: We need to go from individual ions (a part of a molecule) to the larger unit of molecule then to moles. The object changes and we go from units of individual ions to moles.
Step 1 Determine the number of HPO_4^{2-} ions in one molecule of K_2HPO_4. Convert from ions to molecules.
Step 2 In one mole there are 6.02 x 10^{23} objects. In this problem, our object is to find moles of potassium atoms in the molecules of K_2HPO_4; therefore in this instance, so find the ratio of potassium to K_2HPO_4.

$$\frac{5.798 \text{ x } 10^{18} \text{ HPO}_4^{-1}\text{ions}}{1} \times \frac{1 \text{ molecule K}_2\text{HPO}_4}{1 \text{ HPO}_4^{-1}\text{ions}} \times \frac{1 \text{ mole K}_2\text{HPO}_4}{6.02 \text{ x } 10^{23} \text{ K}_2\text{HPO}_4 \text{ molecules}} \times \frac{2 \; mole \text{ K}}{1 mole \;\; \text{K}_2\text{HPO}_4}$$
$$= 1.92 \text{ x } 10^{-5} \text{ mole K}$$

Practice
For hints to solving each problem, and answers, see the list below the problems.

<u>Show all steps on a separate sheet of paper</u>

Sample Problems:
1. How many individual atoms are in a sample of xenon that has a mass of 38.54 grams?

2. What is the mass in grams of 9.35 x 10^{30} atoms of iron?

3. How many moles of sodium are there when you have 6.047 x 10^{28} atoms of sodium?

4. What is the mass of 3.798 x 10^{45} hydrogen (H_2) molecules?

5. How many moles of $CaCO_3$ are there if a sample contains 2.84 x 10^{16} carbonate ions?

6. What is the mass K_2HPO_4 if, when dissolved in water, the sample produces $3.2x10^7$ potassium ions?

7. What is the mass of a sample of KOH if, when dissolved in water, the sample produces $9.84x10^{15}$ hydroxide ions

8. How many molecules of $SrCrO_4$ are in a sample of $SrCrO_4$ has a mass of 24.86 g?

9. How many ions (total) are in 7.45×10^8 molecules of Mg_3N_2?

10. What is the mass of the Mg_3N_2 molecules in problem 9?

11. If we put 3.68×10^{29} atoms of mercury on a gram balance, what would the sample weigh?

12. How many atoms are in a sample of lead that weighs 3.54 g?

13. How many molecules of $Zn(NO_2)_2$ were dissolved into water, if the solution of water and $Zn(NO_2)_2$ contained $3.5x10^5$ nitrite ions?

14. How many nitrogen atoms are in 12.5 grams of $Zn(NO_2)_2$?

15. How many oxygen atoms are in 35.08 g of $Al(OH)_3$?

16. How many sulfite ions are present in 12.5 moles of Na_2SO_3?

17. What is the mass of the sulfite ions contained in 12.5 moles of Na_2SO_3?

18. If we have 6.54×10^8 HCN molecules, how many moles of HCN are there?

HINTS and Answers

1. See Ex. 2. Ans. 1.77×10^{23} atoms Xe.
2. See Ex. 3 Ans. 8.67×10^8 Fe.
3. Ex. 5 Ans. 1.00 x 10 moles Na.
4. Opposite of Example 10. Ans. 1.27×10^{22} g H_2
5. Example 9 Ans. 4.72×10^{-8} moles calcium carbonate
6. Example 9, with the added step of converting grams Ans. $4.6x10^{-15}$ g K_2HPO_4
7. Example 9, with the added step of converting grams to moles $9.17x10^{-7}$ g KOH
8. Ans. 7.35×10^{22} molecules of $SrCO_4$
9. Opposite of ex. 4 Ans. 3.73×10^9 ions total.
10. Opposite of Example 10 Ans. 1.25×10^{-13} Mg_3N_2
11. Ex. 3 Ans. 1.23×10^8 g Hg.
12. Opposite of ex. 3 Ans.1.03x1022 atoms Pb
13. Ex. 4 Ans. 1.75×10^5 molecules $Zn(NO_2)_2$
14. Ex. 7 Ans. 9.56×10^{22} N atoms.
15. Ex. 7 Ans. $8.12x10^{23}$ O atoms
16. Ex. 8 but stop at moles instead of going to grams, or opposite of ex. 5 Ans. $7.53x10^{24}$ sulfite ions
17. Ex 5 and 6 ans. $1.00x10^3$g sulfite ions
18. Ex 1 with molecules instead of atoms ans $1.09x10^{-15}$ moles HCN